Phloem Studies in the Pteridophytes, Part I. Equisetum.

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Xylary tissues of the pteridophytes have been studied in detail by several workers, but phloem tissue has received very little attention. The probable reason for this is the difficulties encountered in studying the anatomical structure of the phloem, for example in cutting perfect radial longitudinal and cross sections of sieve elements showing the details of sieve areas and in staining the tissues.

Little is known about the phloem anatomy of *Equisetum*. I have studied phloem in the rhizomes and aerial shoots of *E. hyemale*, *E. telmateia*, *E. arvense*, and *E. giganteum*. This paper concerns only the latter two species. The purpose of this investigation was to gather data on *Equisetum* phloem that could be compared with presumably comparable tissue described in some American calamites (Agashe, 1964).

Johnson (1933), in discussing the origin and development of certain tissues in *E. scirpoides*, mentioned the occurrence of sieve plates with small pores on the lateral walls of the sieve cells. Golub and Wetmore (1948) described the development of phloem in *E. arvense*. According to them, protophloem sieve cells may be 3 mm long or more. Their longitudinal walls have many, transversely elliptical, faintly staining sieve areas; such areas are also found on the oblique end walls, but they do not seem to form distinct sieve plates. Metaphloem sieve cells are longer, larger in diameter, and have densely granular cytoplasm and very thick walls; sieve areas are more common on the end wall in metaphloem than in protophloem.

There appears to be some confusion in the literature regarding the definitions of sieve cells and sieve tubes. The presently accepted definitions, according to Esau, Cheadle, and Gifford (1953), who quote Cheadle and Whitford, state that a sieve tube consists of sieve elements joined end-to-end to form a vertical tube-like structure in which sieve areas are more highly specialized on the
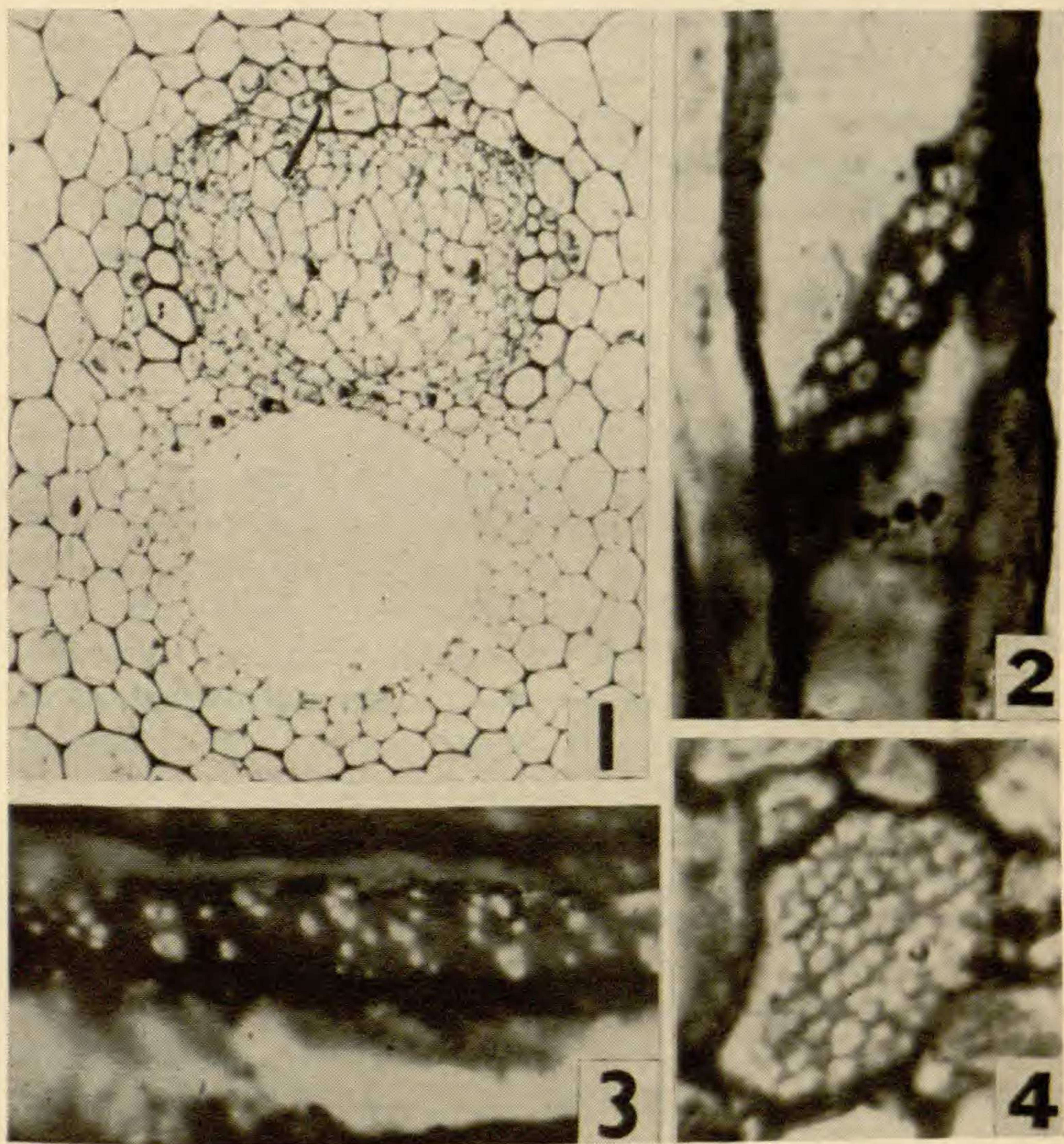
STEM PHLOEM IN EQUISETUM. FIG. 1. TRANSVERSE SECTION OF E. GIGAN-
TEUM SHOWING ONE VASCULAR BUNDLE, × 160. FIG. 2. RADIAL LONGITUDINAL
SECTION OF A SIEVE TUBE OF E. GIGANTEUM SHOWING PORTION OF A SIEVE
PLATE ON AN OBLIQUE END WALL, × 910. FIG. 3. RADIAL LONGITUDINAL
SECTION OF A SIEVE TUBE OF E. ARVENSE SHOWING SIEVE AREAS ON LATERAL
WALLS, × 1385. FIG. 4. TRANSVERSE SECTION OF E. ARVENSE SHOWING A
SINGLE SIEVE TUBE WITH A SIEVE PLATE ON AN END WALL, × 915.

end walls than on the lateral ones. Sieve cells are not joined vertically to each other and have sieve areas on both lateral and end walls which are of similar specialization.

In order to secure perfect radial longitudinal sections of phloem tissue, stem material was split lengthwise and a small piece containing only two or three vascular bundles was selected. This material was soaked in hydrofluoric acid to soften it before embedding it in paraffin. Harris' Haematoxylin was the most suitable stain for sieve elements.

As shown in the cross section of a portion of an aerial shoot of *E. giganteum* (*Fig. 1*), the phloem tissue consists of several cells of two types, and is flanked on either side by radial xylem strands. Just below the phloem is a large protoxylary canal. The whole vascular bundle including the protoxylary canal is surrounded by an individual endodermis marked by a Casparian strip on the lateral walls. Inside the endodermal layer is a single-celled layer of pericycle. The phloem tissue is composed of large sieve tubes and small parenchymatous cells. As shown in the radial longitudinal section of a sieve tube (*Fig. 2*), the end wall is oblique. However, in some sieve tubes the end wall is transverse. Most of the sieve tubes are 30 μ in diameter and 430 μ long. Sieve areas are scattered over the radial walls and include one to three pores. The pores in the oblique end wall sieve plate are 4–5 μ in diameter, whereas most of the pores in the radial walls are 2 μ in diameter.

The most clearly defined sieve plates and sieve areas were observed in the end walls (*Fig. 4*) and radial walls (*Fig. 3*) of the sieve tubes of *E. arvense*, features which have not been illustrated clearly in previous accounts. The sieve areas on the radial walls consist of many pores. In some sieve plates on end walls cytoplasmic strands in the pores can be seen. There seems to be some deposition of callus on the sieve plates.

It can be concluded that the phloem in these species of *Equisetum* is fairly advanced among the pteridophytes because of the presence of sieve tubes and not sieve cells. I am grateful to Prof. Henry N. Andrews for his advice and encouragement and to Mr. S. K. Sutar for his help in preparing the photographs.

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A New Genus of Salviniaceae and a New Species of Azolla from the late Cretaceous[1]

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The Salviniaceae are represented in the Cretaceous by two species of *Azolla* recently described from North America. *Azolla cretacea* Stanley is based on massulae; it has been reported from the Hell Creek Formation of South Dakota (Stanley, 1965), Montana (Norton and Hall, 1967) and the time-equivalent Edmonton Formation of Alberta (Srivastava, 1966). *Azolla geneseana* Hills and Weiner is known both as massulae and megaspores from the Edmonton Formation in Alberta (Hills and Weiner, 1965).

These few reports are scarcely indicative of the place of the family in the Cretaceous, at least in the fluviatile deposits of eastern Montana that I have looked at. By using the simple sieving and sorting techniques customarily used for isolating megaspores from sediments, large numbers of massulae and megaspores of *Azolla* have been found. They are so abundant and heterogeneous as to suggest that the family was not only a conspicuous component of the aquatic vegetation, but was morphologically